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In this paper we develop the semantics of workstation networks in the office in terms of the concepts of application structure and organizational structure of the office. Application structure is concerned with the rules and constraints of the domain of office work such as accounting, law, or social security regulations. Organizational structure is concerned with the social structure of the office as an organization and as such concerns the subsystem components of the office and roles of office workers. Detailed knowledge of office application structures and organizational structures is necessary in order to understand

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how they interact and evolve.
Problem solving is a pervasive activity within offices. It is necessary within the application domain to fulfill the requirements of the application tasks and it is necessary within the organizational domain to understand the influence of the structure of the organization on the application domain. Problem solving is also performed when office workers apply general knowledge about office procedures to the specific cases encountered in their daily work.

We discuss how a description system named OMEGA can aid in the construction of interactive systems whose intent is to describe the application and organization structures. Using the knowledge embedded within itself about the office OMEGA can help support office workers in their problem solving processes.

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1. INTRODUCTION

In this paper we develop the semantics of workstation networks in the office in terms of the concepts of application structure and organizational structure of the office. Application structure is concerned with the rules and constraints of the domain of the office work such as accounting, law, or social security regulations. Organizational structure is concerned with the social structure of the office as an organization and as such concerns the subsystem components of the office and roles of office workers. Detailed knowledge of office application structures and organizational structures is necessary in order to understand how they interact and evolve.

Problem solving is a pervasive activity within offices. It is necessary within the application domain to fulfill the requirements of the application tasks and it is necessary within the organizational domain to understand the influence of the structure of the organization on the application domain. Problem solving is als performed when office workers apply general knowledge about office procedures to the specific cases encountered in their daily work.

We discuss how a description system (named OMEGA) can aid in the construction of interactive systems whose intent is to describe the application and organization structures. Using the knowledge embedded within itself about the office OMEGA can help support office workers in their problem solving processes.

2. WORKSTATION NETWORK SEMANTICS

Although the computer has been used in the offices for many years its use has been limited mainly to highly structured and repetitive tasks in a non-interactive environment. Today we see the use of the computer in a wider variety of areas in the office. Word processing systems, electronic mail systems and other tools based on digital computers are finding their way into the office space proper. Office workers are beginning to have first hand experience using computers. Computers are no longer the mystical beasts available only to an esoteric few.

With this change in the tools available to an office worker has come a realization that there is enormous potential in the use of the computer--especially in networks of interconnected workstations--in the office in novel and as yet unforeseen ways. These new uses will impact the way office work is done in fundamental ways demanding new ideas about how to manage information in an office and a new

conceptualization of what office work is in the presence of new computational capabilities.

As a step toward understanding the impact of this expansion in the use of computers in the office we propose to investigate *Workstation Network Semantics*. In our view workstation network semantics encompasses the study of the two dominate structures in the office--the application structure and the organizational structure--and how these structures interact. The basis of the modes of inter- and intra-structure interaction is through communication of information. Thus communications have content or *meaning* in terms of the application structure and the organizational structure. We couch this meaning or the *semantics* of the communications in terms of the effect of these communications on the subsequent behavior of the office system.

Formalizing and studying the application and organizational structures of office systems is an important goal of our research. We intend to develop a formalization which is implementable on a computer and which has well defined semantics. This has advantages from two perspectives. A formalization allows us to talk about what offices are and what offices do in a more precise manner, free of the ambiguities and imprecision of informal language. With a formalization that has computational underpinnings we can embed the knowledge expressed in the formalization within a computer system itself. Thus we are able to embed knowledge about office systems within the computational systems used in offices. Our belief is that this approach will greatly enhance the capabilities of office computational systems.

Let us consider what we mean by the application structure of an office system. The application structure concerns the subject domain of the office. It comprises the rules and objects that compose the intrinsic functions of a particular office system. In an office concerned with loans the application structure includes such entities as loans, credit ratings and rules such as criteria for accepting or rejecting loans. The application structure of an insurance company is concerned with insurance policies, claims and actuarial tables. The application structure explains the scope of the functionality of an office system on a subject domain as well as providing a model by which those functions are characterized. The application structure is, overtly, the primary reason for the existence of the office.

In contrast to the application structure we have the social structure. Our concern with this aspect of an office system stems from the fact that the activity in the application domain of an office system is realized by people cooperating in a social system. We consider the organizational structure to include both the formal

organizational structure and the informal structure of social relations between the members of the organization. The system of formal controls and lines of authority in an organization have a complementary structure of informal relations among the office workers [Browner et al; 79].

To develop the formalism we need to describe the structures in an office system we draw on ideas and theories from the field of Artificial Intelligence. The formalism we are developing allows us to embed knowledge within a computational system and reason using this knowledge. This allows us to describe and reason about the application structure and the organizational structure. As we describe in the body of this paper the use of a computational description language has many advantages. Its major benefits with relevance to our discussion here are that it will allow the use of computational systems in weakly structured, knowledge rich environments and that it provides a precise language within which to characterize office system.

In the following pages we describe some of the important issues in our resea... on workstation networks. The major emphasis is on organizational structure. We feel that the reason many of the past efforts have been less than successful is due to an overemphasis on the application structure. In this paper we argue that the social structure of the organization has a direct effect on the performance of the organization and that this in turn affects the way new technologies are accepted and used. In the next section we elucidate this point. In the third section we discuss the relationship of Organizations Theory and Artificial Intelligence; we discuss the nature of work in the office and the technology with which this work is accomplished. In the fourth section we describe OMEGA, our knowledge embedding language and describe its use in the *Knowledgeable Office System*. The fifth section discusses the *Actor Model of Computation*, the underlying computational framework upon which the technical aspects of our studies are based. The sixth section describes how each of the subjects in the previous sections need to be combined within the Knowledgeable Office System to form an *interactive* and *integrated* environment.

3. ORGANIZATIONAL STRUCTURE

The study of organizational structure is an important aspect of office systems which has been largely neglected in past efforts to introduce computers into office systems. With electronic office systems as intimately embedded in offices as we propose this neglect is no longer possible. Below we consider some concepts central to this view of office systems.

3.1. Relation to the Environment

An important characteristic of organizations is that they exist in an environment, constantly interacting with and dependent on it. The behavior of an office depends not only on its input conditions but on the conditions that exist in the extra-office environment. In an accounting office the formally required output may be audits but how these audits are created and what they mean depends on tax laws, legislation concerning accounting procedures and the currently accepted body of knowledge about accounting practices. A report of a business entity's financial status has meaning with respect to the process that was used to create it as well as the processes that are used to interpret its significance.

3.2. The Tangibility of the Electronic Office

Computer based office systems are moving in the direction where all office work will be done on or through the computer system. This has profound implications on the way information in the office can be manipulated, stored and accessed.

Mass storage technology is such that large quantities of data can be inexpensively stored compared to paper based storage methods such as file cabinets. This simply means that the volume of information that can be kept for the same price is larger. This trend will continue in the future.

An important difference between paper and computer based storage technologies is accessibility of information. In the computer based system not only can more information be stored for a decreasing price but it can be accessed more quickly and more flexibly than in the paper based system. This affects the way work in the application structure of the office can proceed, but it also affects what the office can know about its own performance. Detailed historical records can be kept and referenced. This adds a dimension of tangibility to the office not present in paper based systems. Performance of the office can be monitored and used to control office activity. However, as we discuss in the next section, this can cause problems as well as have benefits.

3.3. Measurement of Performance

As we saw in the previous section electronic office systems can keep detailed databases of information on the performance of their organization and the individuals within it. This information is useful for *regulatory functions* which gear

office work to certain factors such as production demand. Performance information is also useful for the *adaptive* purposes which seek to help the office evolve so that it may continue to survive in a changing environment. However, care must be exercised about what information is kept and how it is interpreted.

Numbers are exceedingly easy to collect in an electronic office system, but if these numbers are used to drive an adaptive or regulatory mechanism it is essential that an attempt be made to analyze the effect on the future behavior of the office. If this is not the case the resultant behavior may not reflect goals of the organization.

A major problem here is that there is little understanding about how offices work in their day to day operation. Initial performance measurement often points out surprising discrepancies between the believed and actual office performance characteristics. As [Browner et al; 70] point out, the temptation to enforce a particular behavior on an office must be resisted until the implications of the change are well understood. This is particularly true in regard to the effects of an enforced behavior on the social structure of an office.

3.4. Conflicting and Common Interests

Another important function within an office system is making decisions within an office (which we will call the *authority structure* of the office system). A common authority mechanism within offices is a system of checks and balances or *controls* between offices charged with advancing somewhat conflicting interests. An important strategy for maintaining balance is to establish separate groups in an adversarial relationship within an organization to look after conflicting interests. Policies are then established and evolved by negotiation. This strategy is often used in preference to the alternative of attempting to have one group attempt to "rationally" balance the conflicting interests.

Accounting systems are an example where controls are maintained by adversarial relationships between different groups. In many cases accounting systems are required to have certain controls by law, for example. As a result some proposed computerized accounting systems would be illegal to use. This requirement influences the design of office system by placing a constraint on information flow and requires that office systems be designed so users cannot violate these information flow constraints [Bailey et al; 81].

Systems of common interest are used to advantage in offices. It has been noted

[Browner et al; 79] that workers cooperate better and form strong social relationships if they share the goals of a task and are mutually dependent on each other to achieve the goals. Care must be taken to avoid inadvertently upsetting these systems of controls and dependencies.

3.5. Dangers of Separation

Let us consider the situation where word processing centers were introduced in an attempt to increase productivity of typed documents.

The traditional view of secretarial tasks are pictured as comprising such tasks as answering telephones, taking messages, performing administrative duties, making appointments, and typing documents. Word processing equipment is introduced with the intent that operators be trained in the use of word processing machines and be charged with typing whatever documents are delivered to them. The rationale behind this approach was that operators would become proficient at document production with the aid of word processing machines and secretaries would not have to be concerned with document production freeing them to perform their other tasks more efficiently. The hope was that in this way the overall productivity of the office would increase.

To the surprise of some it has been found that the introduction of word processing centers into an organization often has an adverse affect on the production and quality of work in the organization. This stimulated interest in introduction strategies to more carefully control adverse effects. The introduction of word processing centers has had the effect of separating individuals from the semantics of their tasks. The text typed often has almost no meaning beyond the word level to the operators so it is impossible for them to detect important errors and ambiguities and resolve them. The operators have little knowledge about the tasks they are performing; they cannot be as knowledgeable and involved in the task as a secretary who has personal knowledge of the semantics of the material to be typed.

This problem can be explained in terms of a more careful inspection of the secretary's tasks. The secretary's tasks, as expressed by the expectations of his or her coworkers, not only involve those tasks mentioned above but include verification and correction of the information the secretary is concerned with. This stems from the fact that information is often incomplete, ambiguous or in error. The secretaries are familiar with the semantics of the information with which they are working. They know acceptable levels (via norms) of error, ambiguity and incompleteness.

A more subtle problem that arises from the separation of the word processing centers is that they become entities which interact with their customers in more formalized and less flexible ways. The social fabric of the organization changes in such a way as to introduce new authority and managerial issues. This has political implications when information that is likely to be misinterpreted flows outside of the sphere in which it is understood.

3.6. Effects of Social Structure on Organizational Performance

The performance of an organization is directly influenced by the informal social structures among its members. For example:

- The decisions an individual makes that affect a coworker are based in part on the social relationships between the workers. They include the individual's trust in the coworker, his assessment of the coworker's competence, his beliefs about what the coworker knows and his knowledge of the coworker's habits.

- When individuals depend on each other to accomplish the same goals the informal working relations are strongest and the common goal is most easily accomplished. In the case where the relationship is less bidirectional, establishment of the goal becomes a more difficult task to the point that formal sanctions may be necessary to insure that the goal is accomplished properly and in a timely manner.

- Pools of office workers, where each worker is performing the same task tend to form their own informal social hierarchies. The more experienced and skilled workers tend to be accepted as the informal leaders and representatives of the groups. These informal leaders are the ones most likely to form working relationships with managers of the work pools. Via these relationships decisions are made and strategies are planned.

When a new piece of machinery is introduced workers must learn about the technical aspects of the machinery as well as new dependencies and informal understandings. Workers generally learn this kind of information from more experienced members of the office. In the case of new machinery there may be no experienced members and a learning period in which the dependencies and understandings are evolved must be entered. Thus the introduction of new

technology will effect both application structure of the office and the informal social structure. The neglect of the social impact of new technology has caused many problems in the introduction of systems into the office in the past.

4. THE NATURE OF OFFICE WORK FROM AN AI PERSPECTIVE

Of concern to us here is the behavior that organizations exhibit. Organizational behavior is often behavior that is considered intelligent in humans and includes such activity as problem solving, knowledge acquisition and manipulation, and adapting to a changing environment. Organizations exhibit behavior that can neither be implemented given current AI programming methodologies nor can it be explained by current AI theories.

There are many reasons why the study of organizational systems are of interest to AI researchers. Organizations are accessible in a way that humans are not. It is possible to examine the workings of an organization in more detail than it is possible to examine the processes by which a human solves a problem or understands natural language. An organization can be metered, analyzed and experimented with in ways that are not possible with humans. Hypothetical organizational structures can be implemented and examined.

There is a continuum of scale when considering organizations that is not present with humans. At one end of the scale we have an organization composed of a single human. At the other end are organizations composed of many thousands of individuals. This continuity is interesting from at least two points of view. First, we may see how functions present in individuals can be implemented using groups of individuals when the complexity or scope of the functions exceeds the capacity of a single individual. Second, we see various ways in which the functions that organizations perform can be factored as the size of the organization increases.

Many issues that arise in Computer Science and Artificial Intelligence also arise in Organizations Theory. These include distribution vs centralization of resources; coordination and synchronization between processes; control systems; information flow; abstraction and controlling complexity; adapting to a changing environment; knowledge use, manipulation and representation.

The study of organizational systems is relevant to the current interest in the communicating experts metaphors in AI research [Kornfeld, Hewitt: 81]. In these metaphors it is assumed that the complexity and sophistication of human

intelligence arises out of interactions between simple entities or entities of a limited domain of expertise. This is a metaphor readily adaptable to the study of organizations.

4.1. The Pervasive Nature of Problem Solving

Problem solving is a pervasive aspect of office procedures which has been neglected until very recently [Wynn: 1979, Suchman: 1979]. Understanding this problem solving activity is a prerequisite to developing systems which aid in performing tasks that previously have not been amenable to computer processing. Several situations give rise to problem solving activity on the part of office workers. Problem solving is often required within the application domain. Decisions are made concerning the best way, according to some criteria, of obtaining some result. A common task requiring problem solving is to try and diagnose abnormal results of an office procedure. In this case it is necessary to reason about the progress of procedure in an effort to pinpoint the cause for the anomalous behavior. Once this is done further reasoning is necessary to determine what the abnormal effects of the procedure were and how to compensate for them.

Problem solving also arises from the fact that the office exists in an environment and constantly interacts with that environment in implicit as well as explicit ways. Changes in the environment must be detected and compensated for. An accounting office's avowed functionality has little to do with a paper forms supplier or the postal service. But accounting offices frequently interact with these organizations and if these organizations do not behave normally, compensatory action must take place in the accounting office.

This conception of office activity differs from the traditional view that office activity consists of a sequence of well defined steps. Indeed, some office activity does have this characteristic. The areas where computers have made a significant impact, such as accounting and inventory control are areas that are highly structured and repetitive, thus easily formalized in terms of a sequential model. By considering the office from a problem solving perspective we relax the rigid requirements on tasks performed by computers. Important aspects of this view of office activity are:

- **different sets of goals** that evolve over time (these are often implicit in the office procedures and often ill defined);

- **problem solving mechanisms** by which goals may be satisfied in their proper order at the appropriate time;

- **constraints**, derived from the organizational and application domains, within which the office procedures must work.

A difficulty in formally defining the content of office work exists because office workers use their ability to plan and execute, in the face of unexpected contingencies, actions that achieve the goal of the office work. What is really desired is the knowledge that drives the planning process and knowledge about how the problem solving process works.

More knowledgeable office systems can help the office workers by supporting them in their problem solving activity. Analysis of past activity helps diagnose abnormal office procedures and descriptions of postulated activity help determine the consequences of future actions. With descriptions of tasks embedded within a computer system the computer system can aid the office worker. The computer system can determine what the goal of current activity is, what possible ways may exist for achieving the goal and when the goal is actually realized.

4.2. Explicit Representation of Goals and Constraints

Office workers are able to handle unexpected contingencies in their daily work because they know the goals of the office work and because they know the constraints that must be maintained during the execution of the office work. These goals and constraints are often implicit in the work and in the office workers' knowledge of their work. Thus it is hard for a computer or another human being to understand the decisions an office worker makes in planning a problem solving strategy to handle unexpected contingencies.

To support the problem solving activity in office work knowledge about the goals and constraints of the office work is explicitly represented. This builds a teleological structure of the office work within the computer. Actions that would be performed during the course of the office work are linked to the reasons they are performed and to the constraints that they are required to maintain. Explicit representation of the goals and constraints exposes hidden assumptions about the office work and makes the actions performed by an office worker more understandable by machine or by another individual.

The explicit representation of goals and constraints provide a recourse to handle unexpected contingencies. If a particular action cannot be performed the computer system can possibly suggest an alternative action. Failing this the office worker can use the computer system to examine the goals and constraints of an action that cannot be performed. Together, the office worker and computer system can construct a new plan of action that maintains the necessary constraints and makes progress toward achieving the goals in question.

4.3. Organizations Theory and AI

Our underlying interest in the study of organizations is to consider the relationship between the technology used to accomplish work in the office and the work that needs to be done. The characteristics technology for the office must have can be derived from several considerations. First, using people vs using people and machines to accomplish the knowledge processing. Second, the open-ended character of knowledge in the office world and third, the resource consuming nature of decision making in order to achieve goals.

One can ask the questions "What have the years of study in Organizations Theory produced?" "What can Artificial Intelligence contribute?" "Is the wheel about to be reinvented again?" To answer this question we consider the following view of *organizations.* There is a kind of work that organizations--especially information intensive organizations such as offices--perform and there is a technology by which this work is accomplished. By and large the technology by which the work is accomplished has largely consisted of paper-based and verbal communication, paper-based storage of information, and the members of the organization. The relation between the work offices accomplish and technology used to accomplish it has not been of concern because it has not changed until recently. Thus organizations theory has not dealt with the question of the relationship between work in the office and how it is done. Much can be gained by examining the work in the office as knowledge manipulation and problem solving activity.

The relationship between work and work technology has been an issue in more routinized, production line style, non-information related tasks. There has been much study in the name of Management Science and Industrial Engineering as a result. Within the office there has been the use of centralized computer facilities for accounting and inventory. Both of these functions have a highly structured and rigid interface to the workers in the office. In their capabilities they are extensions of the paper based systems. Technology impacting the work in the office has been limited

to devices such as the batch computer facilities, telephone, typewriters and recently, word processing. The introduction of each of these has impacted the way office work is done. The impacts have been handled on a case by case basis; no theory of what is happening when new technology is introduced exists. The unpredictable results of the efforts to introduce word processors into office is testament to the fact that both the relationship between technology and office work is not well understood and that office work itself is not understood. In the cases of the technologies mentioned above the work in the office, the thinking, the knowledge processing, has not been impacted in any significant way. Certainly not as drastically as it will be in the years to come.

5. THEORETICAL FOUNDATIONS

In this section we discuss the theoretical foundations of Workstation Network Semantics. We first consider the description system OMEGA, the knowledge embedding language. Following this we discuss the concurrent systems theory that forms our foundation for understanding and building distributed computer systems.

5.1. The Description System OMEGA

We are developing a description system (named OMEGA) to embed knowledge about offices into an electronic office system [Hewitt, Attardi, and Simi: 1979] Descriptions are used to describe the properties of objects in an office. Within an office system descriptions are used to embed knowledge about office procedures and the tasks of office workers as well as replace current day paper forms. Descriptions perform several functions that were heretofore entrusted to forms such as:

- **Storage of information** as in records.
- **Transfer of information** as in messages.
- **Display of information** in an abstracted and structured manner.
- **Accumulation and modification of information** as the form is used by individuals in the accomplishment of their tasks.

Descriptions provide some of the functionality of an automated forms flow system. Descriptions are a very general facility; one of their uses is to support electronic forms but they are used for much more general knowledge embedding purposes.

Descriptions are of underlying importance within OMEGA; they express relationships between the objects in the electronic office system. A form is the visual manifestation of a description. An electronic system with descriptions stores the information contained in descriptions in an inheritance hierarchy. Those descriptions which are forms are displayed on video devices for perusal and modification. In addition to the capabilities supplied by forms, descriptions function in additional capacities:

- Descriptions are a **means for error checking** of information in an office system.

- Descriptions are a **basis for retrieval** of stored information.

- Descriptions are a means by which the **structure of the application and organizational domains** of an office system are specified.

- Descriptions determine the **semantics** of entities in an office system via their specified relationships to each other.

- Descriptions relativized to **View points** are a means of dealing with change and avoiding inconsistent states.

The added dimension descriptions give to an office worker is exhibited in the following example. An office we have studied which is part of the Department of Defense is one in which officers are assigned to new tours of duty after their current assignment expires. In this system often an Assignment officer is asked questions about data in forms such as: "How many officers above the rank of captain are at sea and are due to roll within the next six months?" Questions of this type have the characteristics that their specifics cannot be anticipated and that they require a tedious, time-consuming search of large amounts of data. A retrieval facility allows a user to fill in an example description with variables and conditions and use the example description to match against stored descriptions. This scheme gives a user the power to easily express a wide variety of questions similar to the one above. It is related to but more general than such systems as Query By Example [de Jong and Zloof: 1977] in that information exists in a semantic hierarchy and thus may be accessed in terms of its semantic properties as well as in terms of predicates on the information itself.

A mechanism supplied by OMEGA is the viewpoint mechanism. Viewpoints are a means by which to relativize descriptions to time. Thus they are used to indicate

when a description is applicable. Viewpoints themselves are descriptions and thus there is full generality in describing viewpoints and the relationships between viewpoints.

Descriptions provide a means by which to embed knowledge about offices and office procedures within an office system. We refer to such a system as a *knowledgeable office system*. The structure of office procedures is described in terms of their goals, the environmental constraints under which they must operate and the tasks of individuals involved in those office procedures. This knowledge can be used in many ways. It can be used to predict what information may be needed by the office worker as he attempts to solve the problems posed to him by his tasks. Descriptions form a basis within which to express and maintain the status of goals and the relationships between interacting goals. In an interactive environment descriptions serve as a basis within which to interpret basic commands and commands programmed by the user.

The office worker must be able to program his work station to help him accomplish his tasks but this programming must be done in a different manner than it is currently. It is undesirable that someone concerned with assigning officers to new duties communicate with his work station in terms of integer variables or iteration constructs. The worker must be able to communicate in the language in which he thinks and he must be able to develop programs in as painless a fashion as possible. An alternative to the traditional programming practices is a methodology known as *concrete programming* [Lieberman and Hewitt; 80]. In this approach a user defines the effects of a program in a piecemeal fashion by using operations on concrete, example data items in a manner similar to the way he would normally perform the procedure. This allows the user to see the effects of his program as he builds it, partially dissolving the dichotomy between running and writing programs. In this manner programmed office procedures emerge from solving concrete problems in the course of daily work.

5.2. Concurrent Systems

As a computational framework for our ideas we are developing the Actor theory of computation. Part of this work involves the design of programming languages like ACT1 [Hewitt, Attardi, and Lieberman: 1979] and ETHER [Kornfeld: 1979] and part involves the mathematical definition of the semantics of these programming languages. There are two reasons that concern us here why we feel that a language with well understood semantics is necessary for the design of office information

systems; these pertain to *guarantee of service* properties and the implications of the order of arrival of messages.

Whenever communicating programs execute on a computer system the problem of guarantee of service arises. Guarantee of service is important to insure that in situations where requests are constantly competing for a system's resources all requests made are serviced. Thus within the office environment consider a case where many loan applications are submitted to the office system over a period of time. A property one would desire to prove is that each loan application submitted will be processed and in time will result in a response, be it an acceptance or a reason for rejection. It is a theoretical property of some computational models that guarantee of service cannot be insured. An advantage of building a system in the Actor Model of computation is that guarantee of service properties can be established and implemented. For example, in [Hewitt, Attardi, and Lieberman: 1979] an implementation of a hard copy server is given along with a proof of guarantee of service.

An additional reason important to provide a precise mathematical definition of a programming language to be used in an office system is that the meaning of the different kinds of messages arriving at workstations and the actions they evoke are very dependent on the order in which the messages arrive. Concurrent ystems Theory supplies the concepts with which to talk about the arrival orderings of messages and the consequences of the possible arrival orderings.

Actor theory formalizes and describes the behavior of objects called actors as they communicate via message passing. In this model all computations are represented by message passing between actors. The receipt of a message by an actor may trigger additional messages sent to other actors thus continuing the computation. This model is particularly well suited for application to the office environment because activity in both the Actor model and the office is driven by the receipt of messages. Activity is initiated when a message is received, be it a loan application, a message triggered by the time of day, or a message that asks for the square root of a number.

The communication in the Actor Model and much of the communication in offices is unsynchronized communication. The intended recipient need not be ready to accept a message before it can be sent. In an office many messages are sent without requiring that the intended recipient be in a particular state at the time of transmission. A mail system is an example of unsynchronized communication while a telephone exchange between caller and answerer is synchronized communication.

Note that an important task a secretary performs is to answer a telephone and take messages. These messages will then be delivered to the intended recipient at a later, more convenient time. The telephone is a fast way to send messages but it requires that someone be present to answer it; it is synchronized communication. Synchronized communication places heavy constraints on the communication mechanism since both parties must synchronize before a message can be exchanged. The secretary often functions to desynchronize messages that need to be transferred quickly.

6. AN EVOLUTIONARY, INTERACTIVE ENVIRONMENT

An area where much effort is expended in an office system is in attempts to deal with change, both within the system itself and between the system and the environment it exists in. Viewpoints are a technology which we are developing to address this problem. They allow changes to be considered in a consistent manner by relativizing the information before and after the change to different viewpoints and describing the relationship between the viewpoints.

Office systems must be flexible and able to adapt to change. As workers become more adapted to the use of more sophisticated electronic office tools deeper organizational changes may begin. As our understanding of the office increases more applications will arise. Technological advances engender changes in hardware and software. An office system must be able to incorporate new technology as it appears. The office exists in a changing environment and it must be able to adapt in order to continue achieving its goals. For example, if the tax laws are changed it must be possible to reflect this change quickly and easily in an office system that is concerned with taxes.

An interactive, knowledgeable system has the goal of supporting the problem solving activity which takes place in offices. This requires that the system have detailed knowledge of the application structure and organizational structure of the office work. Much of this knowledge concerns the goals of individual office procedures and the constraints within which they operate.

Many facilities such as mail systems, text editing systems, and database systems are beginning to appear in the office. These products have been implemented as separate systems on timesharing computers or sometimes on separate machines. The approach of using independent systems has the limitation that shared objects are limited to character strings that are transferred via pipes or files. The result is

that use of these facilities in a cooperative manner to accomplish tasks is cumbersome. If a system is going to manage office procedures knowledgeably, facilities that are used during the execution of the procedures must be in a more intimate relationship with each other.

The fragmentary nature of nonintegrated computer system implies more than the technical problems of sharing objects between systems. Separate systems pay the penalty of contributing to incoherent and redundant systems. Often different sets of commands must be learned that have similar results or worse yet, similar commands having different effects. This results in complicated and difficult to understand systems.

Added coherence between different functional elements of a system has the benefit that the user's actions and the goals of the office procedure can be understood in terms of each other. It is useful for the system to understand the goals in order to interpret the user's requests and suggest problem solving tools r achieving the goals. In turn the user's actions suggest what the current goals are and narrows the variety of problem solving methods and size of the solution space.

7. CONCLUSIONS

We believe that the time has come to begin the development of Workstation Network Semantics as a field of endeavor which studies the meaning of messages sent in an office. These messages have meaning from several points of view. These messages reflect the application structure and organizational structure of offices including office organization, office procedures, as well as issues of power and control that arise in negotiations. A message has a social content. A message has application content. For example, messages concerning purchase orders or requisitions must obey certain rules and regulations. From the point of view of both applications and interpersonal relations, a message has timing content. For example, a request to withdraw money from a checking account can have different consequences depending on whether it arrives before or after a deposit message.

Much of the work performed by office workers has important problem solving aspects. Future electronic office systems must support this problem solving activity. This is one reason why it has been so difficult to extend sequential, algorithmically oriented programming languages such as COBOL and PL/1 to new office applications. The goals of office procedures need to be understood by any electronic office system used by the workers. Research should be directed toward

the goal of developing interactive support systems to aid office workers in their daily problem solving activities. Such systems must have knowledge of the goals and constraints of office procedures in order to provide effective support for office workers in using their workstations.

It is very important to consider the sociological impact of electronic office systems. Knowledgeable office systems must be designed to *meet* the organizational structure at the time of their introduction and then *evolve with* the organization. The negotiation activity necessary to balance interests among competing groups must be maintained. New ways of structuring the office must be judged in light of their impact on the semantics of work including the application, timing, and organizational content of messages. New ways of measuring performance need to be evaluated in terms of their impact on the semantics of the work performed.

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Most of the ideas in this paper are not original with us. Many of them emerged repeatedly in the "Electronic Office of the Future" workshop held at MIT in January 1979. Our insights on the pervasive and central role played by problem solving in office procedures build on the work of Lucy Suchman and Eleanor Wynn.

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